ONTARIO WATER RESOURCES COMMISSION

RESEARCH
PUBLICATION
NO. 12

THE USE OF DEEP LAGOONS FOR THICKENING AND DRYING OF DIGESTED SLUDGE

THE ONTARIO WATER RESOURCES COMMISSION

THE USE OF DEEP LAGOONS FOR THICKENING AND DRYING OF DIGESTED SLUDGE

By:

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June, 1966

Division of Research
Publication No. 12

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THE ONTARIO WATER RESOURCES COMMISSION

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SUMMARY

The Division of Research, Ontario Water Resources Commission, has conducted pilot plant and model studies of the effectiveness of deep lagoons (greater than 4 foot depth) for the drying and/or thickening of digested sludge.

It is concluded that deep lagoons are not effective in producing a dry sludge.

Lagoons are effective in producing a thickened sludge (up to 50% reduction in volume) and thus may be economically feasible as a method of reducing sludge disposal costs.

Lagoons may produce a sludge of such consistency, if used to maximum capacity, that pumping will be difficult, if not impossible. It may be necessary therefore to utilize sludge lagoons to less than their theoretical capacity in order to facilitate ultimate disposal of the sludge.

1.0 INTRODUCTION

Lagooning of sludge, either for drying or thickening, has been carried out at several sewage treatment plants in the Province, but, to date, there has been very little published information as to design criteria or process efficiency.

In April of 1964, the Ontario Water Resources Commission authorized the Division of Research to carry out a pilot plant study of lagooning as a method of sludge drying and/or thickening.

The Lakeview sewage treatment plant was chosen as the site of the pilot plant because of the availability of suitable land area, the reliability of the sludge supply and its proximity to the OWRC laboratory.

Three lagoons were constructed, as detailed in the following section, each with a different depth, so that a comparative study of the sludge dewatering characteristics and sludge loading potential could be carried out. In addition to the lagoons a supernatant pond, and later, three shallow drying beds were constructed.

2.0 DESCRIPTION OF FIELD FACILITIES

2.1 GENERAL

Three sludge lagoons, a supernatant pond, and three sludge drying beds were constructed as shown in Figures 1 and 2.

The soil at the construction site is a clay-loam type, relatively impervious to water. This material was used in the construction of all cells, with no material being imported.

2.2 SLUDGE LAGOONS

The three sludge lagoons were each constructed with different depths.

Lagoon No. 1 measured 75 ft. x 200 ft. (dimensions taken to inside top of berm) with 1:1.5 (V:H) inside berm slopes and a depth of 10 ft. Filled to a depth of 9.5 ft. the lagoon contained approximately 650,000 gallons.

Lagoon No. 2, 50 ft. x 140 ft., was constructed with 1:2 inside berm slopes and a 6 ft. depth. Filled to a depth of 5.7 ft. the lagoon contained 152,000 gallons.

Lagoon No. 3 was similar in dimensions to No.2 (50 ft. x 140 ft.), had 1:2 slopes on the berm interiors, but had a maximum depth of 4 ft. Filled to a depth of 3.75 ft. the lagoon contained 112,500 gallons.

The different depths were constructed in order that the effect of depth on thickening or drying might be evaluated.

2.3 SUPERNATANT POND

The supernatant pond, 43 ft. x 114 ft. x 6 ft. deep, with 1:2 interior berm slopes was constructed so that supernatant from any or all of the sludge lagoons could be decanted to this pond and subsequently pumped back to the sewage treatment plant for re-treatment.

2.4 THICKENED SLUDGE BEDS

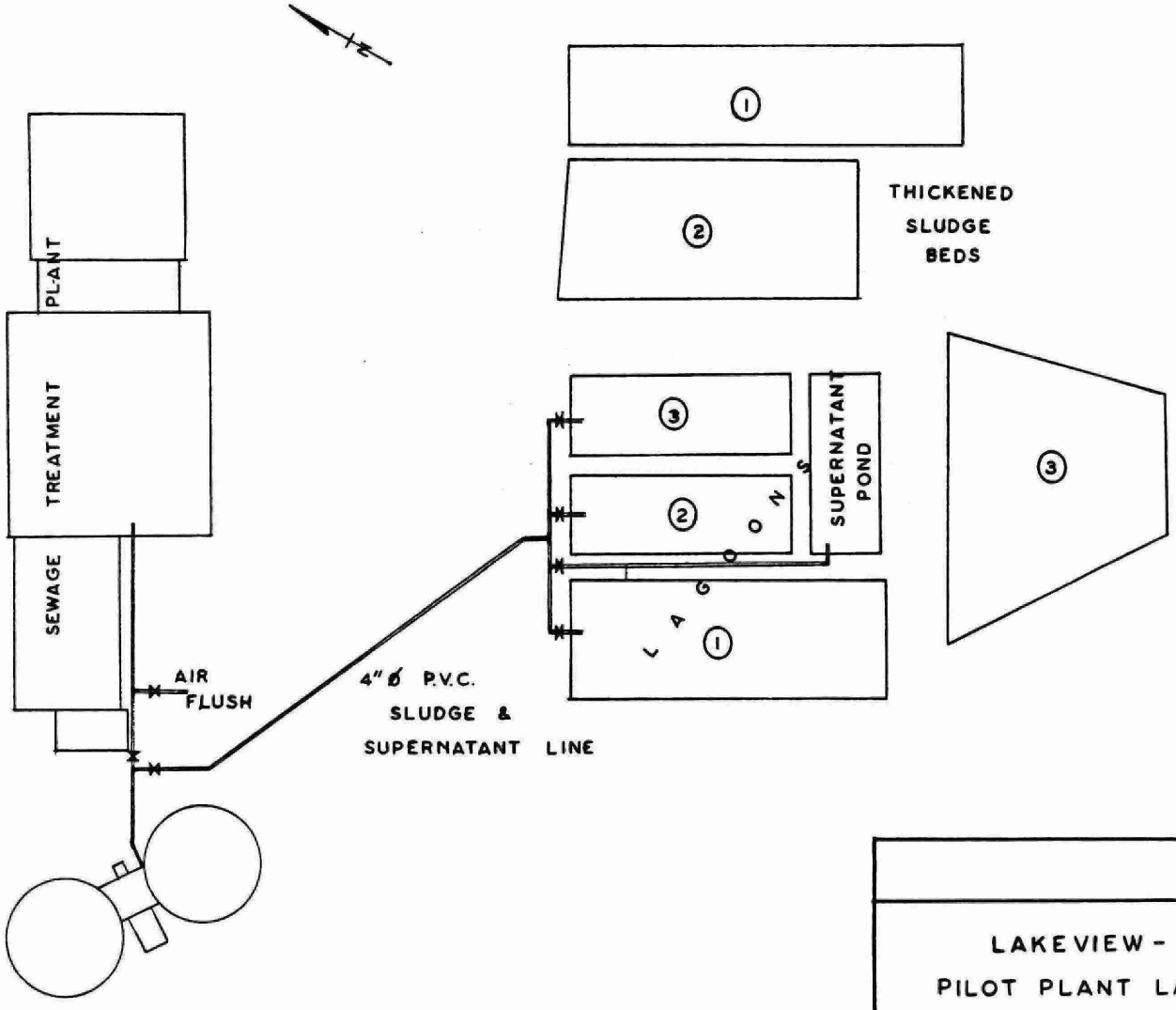
Three "thickened sludge beds", as shown on Figure 1, were constructed with 18" sidewalls. Sludge, after thickening in the lagoons, was pumped to these beds for further drying and ultimate disposal.

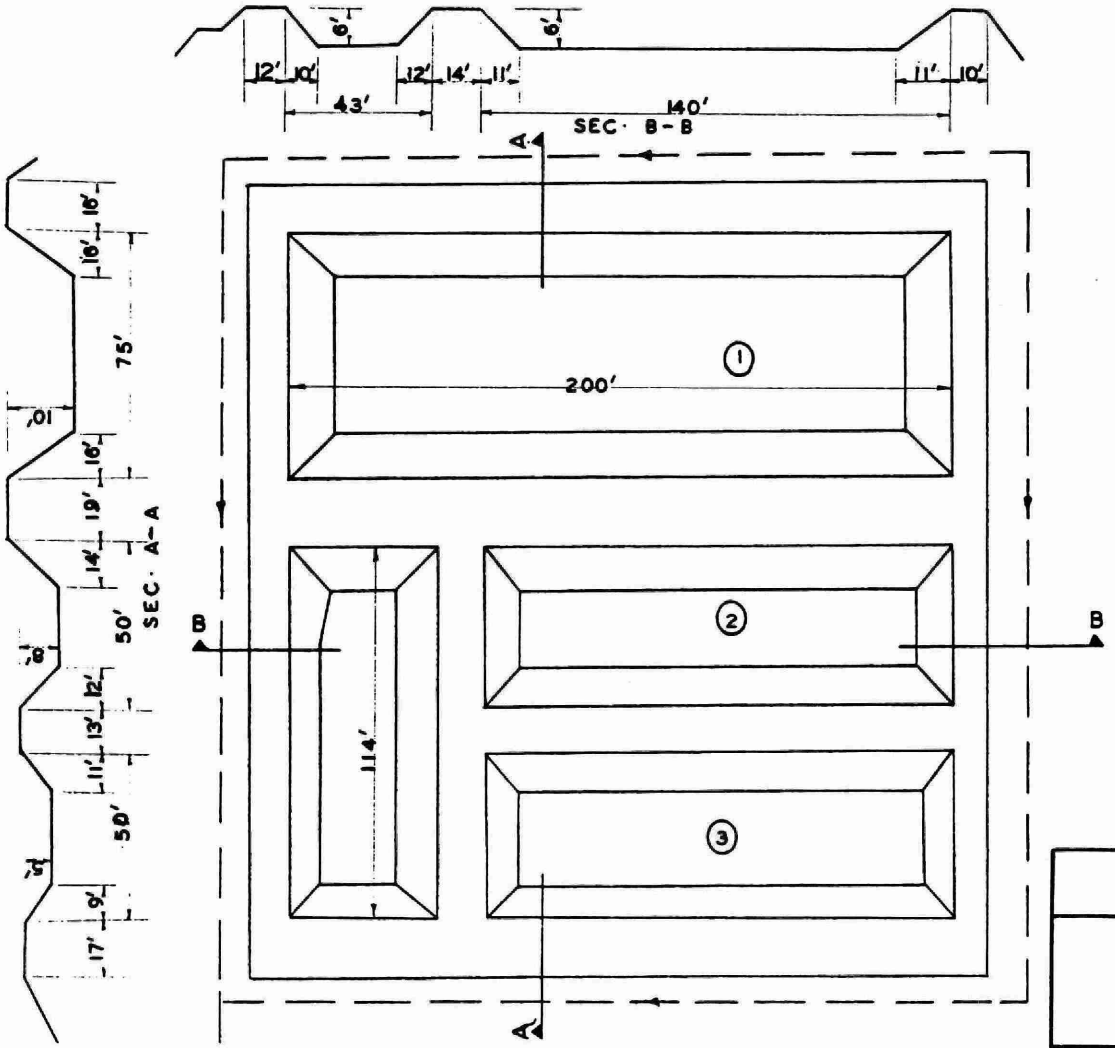
2.5 PIPING

A 4" diameter P.V.C. pipe was installed as shown in Figure 1. The piping arrangement was such that sludge from the secondary digester could be pumped to any or all of the sludge lagoons, or alternately, supernatant from the supernatant pond could be pumped back to the primary or aeration section of the sewage treatment plant.

2.6 SUPERNATANT DRAW-OFF

Supernatant from the sludge lagoons was decanted to the supernatant pond by means of a portable syphon. Several arrangements were tried, the most successful consisting of a suction hose floating just below the supernatant surface (suspended from a wooden float) free to follow the liquid level and connected to an "Edson" hand operated diaphragm pump. The pump discharge was in the supernatant pond at a level below the sludge lagoon surface level. A syphon could then be started by manually operating the diaphragm pump and would continue until the suction end reached heavy sludge which would stop the syphoning action.


PLANT
TREATMENT
SEWAGE
AIR
FLUSH
4" Ø P.V.C.
SLUDGE &
SUPERNATANT LINE
1
2
THICKENED
SLUDGE
BEDS
3
SUPERNATANT
POND
3
2
1
LAGOON
LAKEVIEW -
PILOT PLANT LAYOUT
1" = 100'
FIG. 1



SLUDGE LAGOON
DETAIL

1" = 50'

FIG. 2

3.0 FIELD TEST PROCEDURE

3.1 GENERAL

The field installation was operated by the staff of the Lakeview sewage treatment plant. Rather than attempt to simulate ideal conditions for the operation of the lagoons, they were instead used under obtaining practical conditions. Decants and sludge additions were made when sufficient volumes of supernatant were available. During the winter the lagoons were not loaded.

3.2 SLUDGE LAGOON No. 1

Filling of lagoon No.1 was started on October 8,1964 and additions of approximately 30,000 gallons per day were made until November 3. During this period approximately 48,000 gallons of supernatant were removed. From November 3 until April 28, 1965 when this test was terminated (total period of 202 days) supernatant was withdrawn when available and an equivalent volume of sludge added. Measurement was made only on sludge additions, such additions being equal in volume to the amount of supernatant removed. (See Figure 3)

The sludge in lagoon No. 1 was pumped out to the thickened sludge beds during May of 1965 until only a 2 foot depth remained in the lagoon. This material could not be moved by a pump.

Calculations were made to convert this remaining sludge to a theoretical equivalent volume of unthickened sludge for purposes of analysing data.

Lagoon No. 1, test B, began on May 30,1965 and was terminated on August 10, for a total period of 72 days, plus 35 days adjustment for pond contents at start of the test.

Decanting and sludge additions were carried out in a manner similar to those of test A. (See Figure 4)

Test C, carried out from August 20, 1965, until December 13, 1965 (115 days plus 55 days adjustment for pond contents at the start of the test) was conducted in a manner similar to the previous two. (See Figure 5)

3.3 SLUDGE LAGOON NO. 2

The procedure for tests on lagoon No.2 was similar to that used in tests on lagoon No.1. Filling of lagoon No.2 was started on October 8, 1964 and testing terminated on December 9, 1964 for a total test period of 426 days. No decants or sludge additions were made for a period of approximately 150 days during the winter of 1964-65. (See Figure 6)

3.4 SLUDGE LAGOON NO. 3

The test procedure used for lagoon No.3 differed from that used for the other two lagoons in that only one decant was made during the test period, after which the lagoon was refilled and left to dry. Filling was started on October 14, 1964, the pond was full on November 20, 1964, 32,600 gallons of supernatant were decanted on December 4 and the pond had been refilled by December 11. No additions or decants were made until April 28, 1965 when 36,300 gallons of supernatant were withdrawn and the pond was left with no further addition. The test was terminated on April 5, 1966. (See Figure 7)

3.5 DISPOSAL OF SUPERNATANT AND THICKENED SLUDGE

Supernatant was decanted from the sludge lagoons by a syphon, as detailed in section 2.6 and held in the supernatant pond until the volume warranted pumping it back to the sewage treatment plant.

Thickened sludge pumped from sludge lagoon No. 1 at the termination of tests A and B was pumped to the thickened sludge beds where it was left to dry. The depth on these beds did not exceed 12 inches. A portable gasoline powered diaphragm pump was used for sludge withdrawal.

LAGOON No. 1

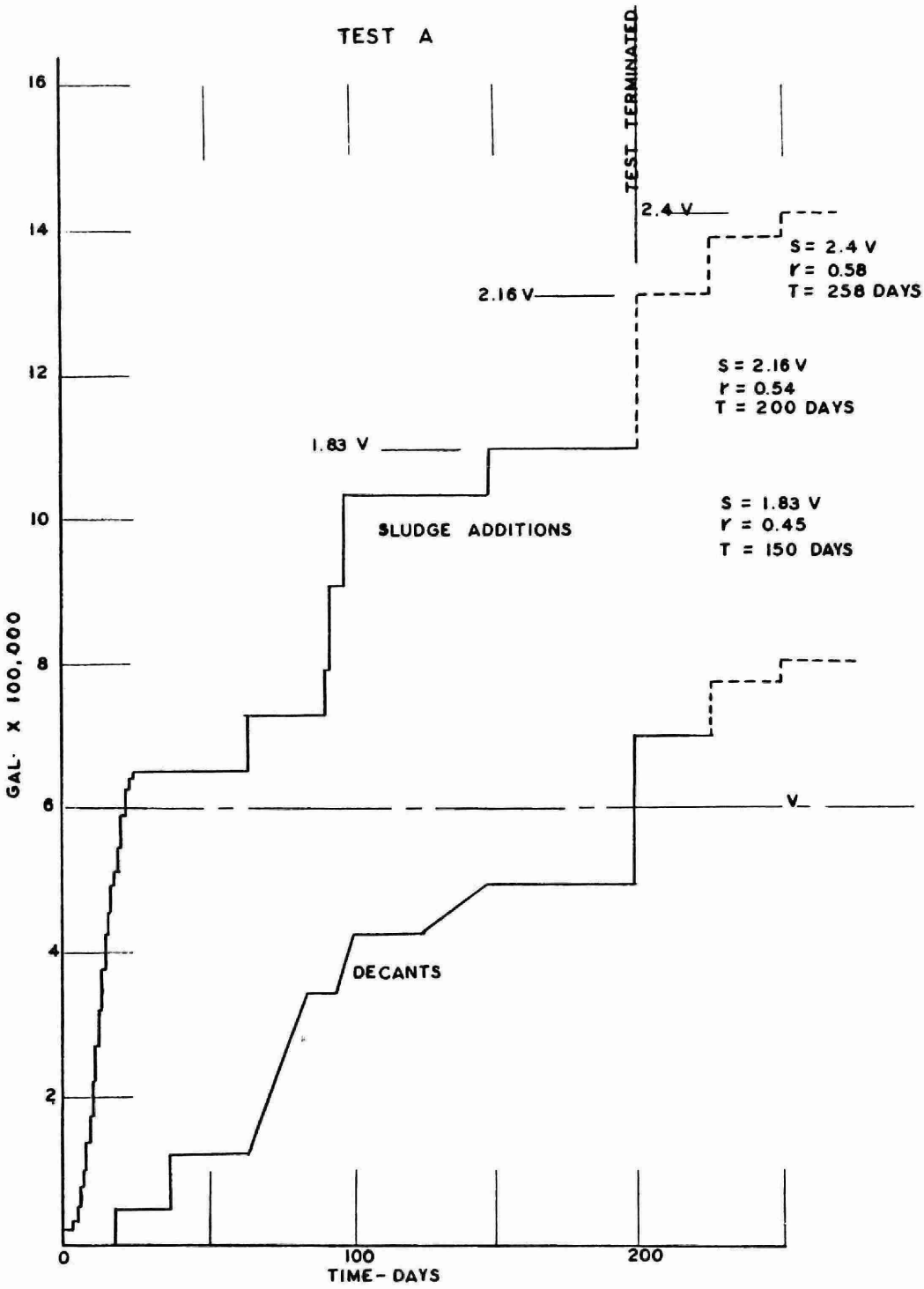


FIG. 3

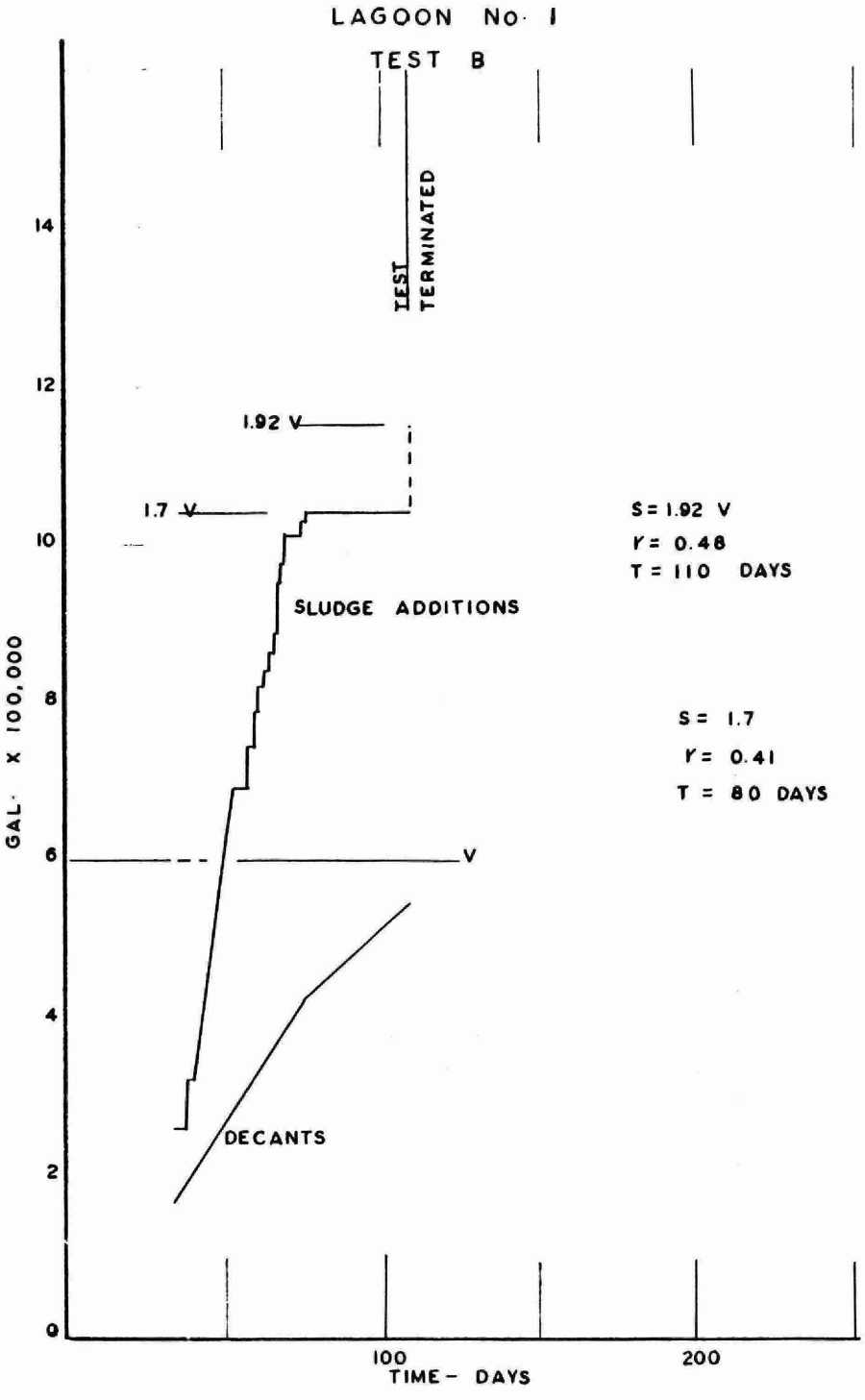

LAGOON No. 1
TEST B
TEST TERMINATED
14
12
10
8
6
4
2
0
GAL. X 100,000
1.92 V
1.7 V
V
SLUDGE ADDITIONS
DECANTS
S = 1.92 V
Y = 0.48
T = 110 DAYS
S = 1.7
Y = 0.41
T = 80 DAYS
100
200
TIME - DAYS

FIG. 4

LAGOON No. 1

TEST C

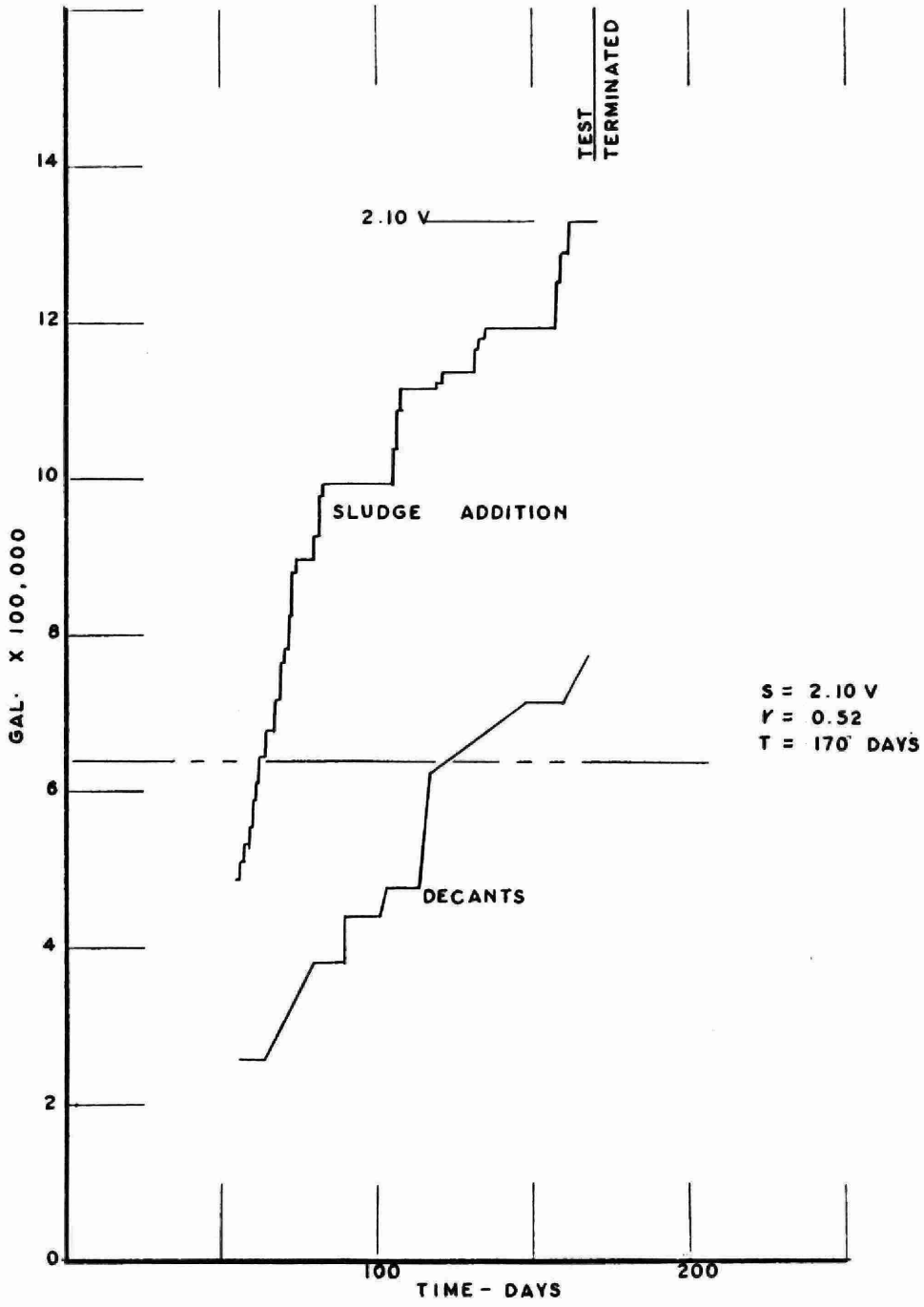


FIG. 5

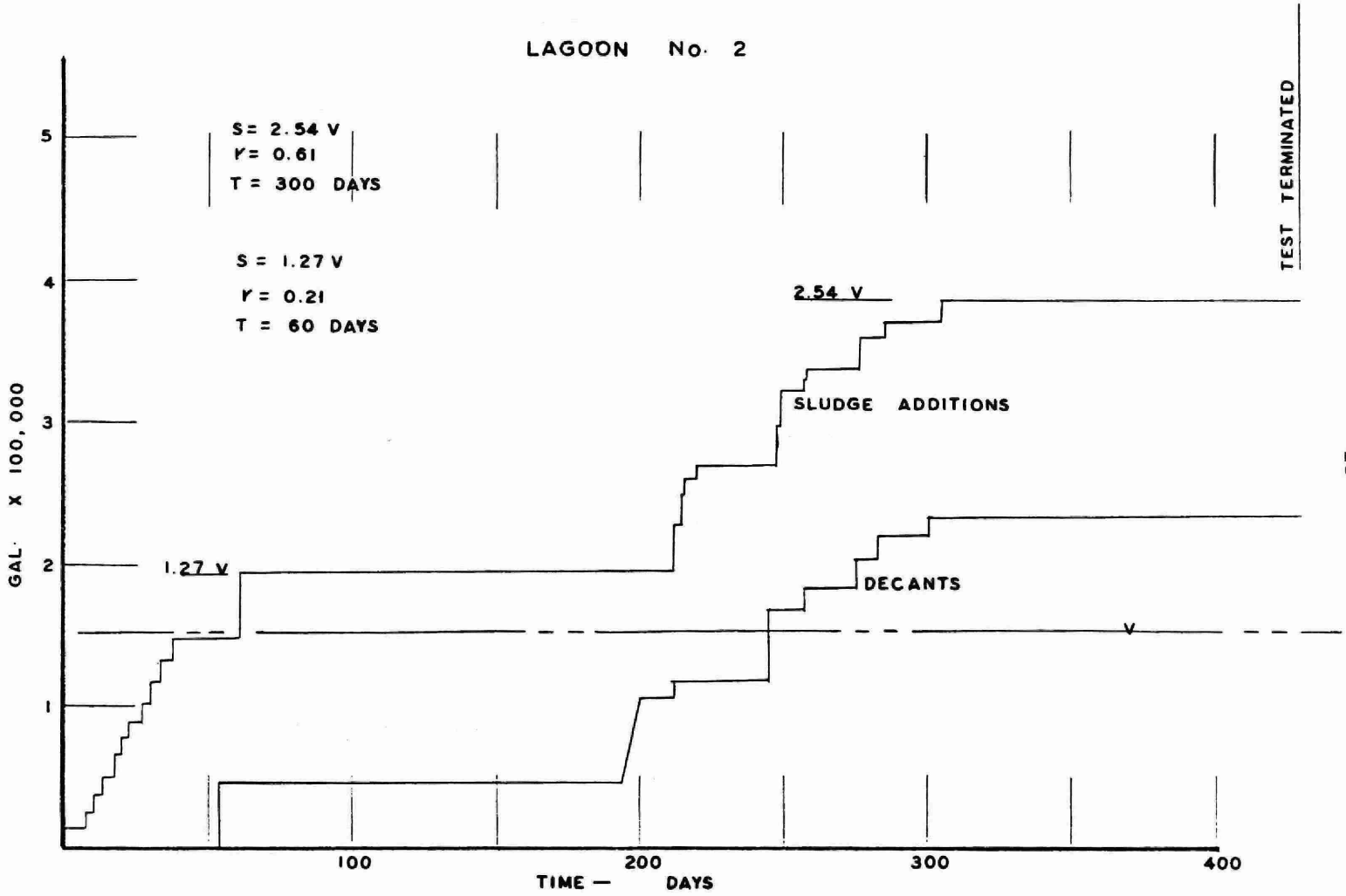

LAGOON No. 2
S= 2.54 V
Y= 0.61
T = 300 DAYS
S = 1.27 V
Y = 0.21
T = 60 DAYS
TEST TERMINATED
2.54 V
SLUDGE ADDITIONS
1.27 V
DECANTS
V
GAL. X 100,000
1
2
3
4
5
100
200
300
400
TIME — DAYS

FIG. 6

LAGOON No. 3

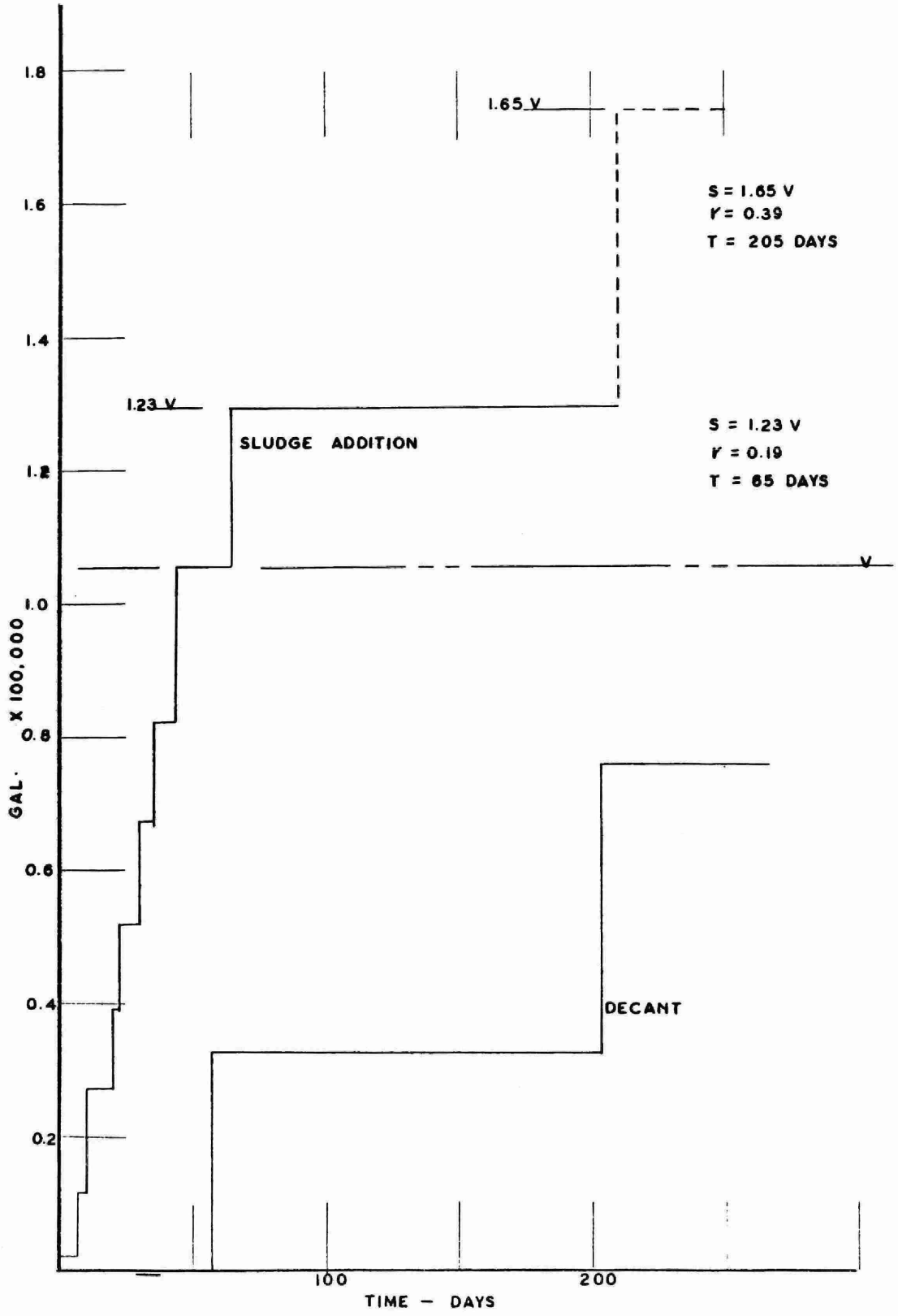


FIG. 7

4.0 FIELD TEST RESULTS

4.1 GENERAL

The results of the field testing of full scale sludge lagoons indicated that variation of depth from 4 to 10 feet produced no noticeable effect on operation or efficiency of the lagoons. Results also indicate that deep lagoons are effective in thickening sludge but are not effective for drying.

4.2 SLUDGE LAGOON NO. 1

Three tests were carried out on lagoon No. 1. In each case the operating procedure was similar sludge addition, supernatant decant when available and refilling with sludge. (See Figures 3, 4 and 5 and Tables I, II and III)

The operation of the beds approximated a geometric progression of the form:

$$S = V\frac{(1-r^n)}{1-r}$$

in which S = the sum of n terms

V = initial pond volume

r = ratio of supernatant to sludge

n = number of terms

In the case of the sludge pond "n" effectively approaches infinity and therefore:

$$S = \frac{V}{1-r}$$

in which S = total "pond volumes" used

V = full pond volume

r = % reduction ÷ 100

Calculation of the values of S, and r for periods of operation, T, are given in Figures 3, 4 and 5. Values of r, expressed as percent reduction are given in Figure 8.

In Tests A, B and C, sludge addition was terminated after 1.83, 1.7 and 2.10 times the full pond volume had been applied respectively. This is equivalent to sludge volume reductions of 45%, 41% and 52% respectively, in periods of 150, 80 and 170 days respectively. These results are shown in Figure 8.

The tests were terminated, not because further pond usage was impossible but because the remaining sludge was approaching a consistency too thick to pump and yet too thin to remove by power shovel. As shown in Tables I, II and III the average sludge solids content was approximately 7% but this varied from 5% to 12% (approximately) from surface to bottom of the pond. In emptying the pond the material near the bottom could not be pumped.

These results indicate that if sludge removal by pumping is required, sludge lagoons should not be used to their full capacity for thickening. (Theoroetical capacity is shown by dotted lines on Figure 3)

4.3 SLUDGE LAGOON NO. 2

The operation of lagoon No. 2 was similar to that of No. 1 except that the lagoon was not loaded during the winter. The operating procedure is illustrated graphically in Figure 6 and in tabular form in Table IV.

Calculations of volume reduction based on a geometric progression are given in Figure 6 and are plotted as percent reduction against time in Figure 8.

In lagoon No. 2 sludge additions equal to 2.54 times the full pond volume, made over a period of 300 days, resulted in an average solids content of the remaining material of 9.7%. Withdrawal was difficult and incomplete

by pumping.

Again, as in the case of lagoon No.1, the results indicate that if sludge removal by pumping is required the pond should not be used to its maximum efficiency but rather to an optimum point.

4.4 SLUDGE LAGOON NO. 3

As detailed in section 3.4, the test procedure used for Lagoon No.3 differed from that used in Lagoons No. 1 and 2, in that only two decants of supernatant were made and the pond contents were left to dry.

Figure 7 illustrates the addition and decant procedure graphically. Table V presents a tabular illustration of the procedure.

An examination of the results given in Table V indicates that in the period from April 28, 1965 to June 11, 1965, the pond contents decreased by approximately 26,000 gallons. This is attributed to evaporation. However, in the period from June 11,1965 to April 5, 1966 the pond contents increased by approximately 46,000 gallons. This increase is attributed to a net gain in precipitation over evaporation.

These results indicate that deep sludge lagoons are not reliable as drying beds but are subject to meteorological conditions. It was noted that evaporation of the sludge proceeded rapidly until a dry crust approximately 3 inches thick developed which limited further evaporation. Rain and snow wetted this crust and soaked through. The cycle then repeated.

Meteorological records for the period April,1965 to February, 1965 (See Figure 9) indicate that "pan evaporation" exceeded precipitation but this condition did not obtain in lagoon No. 3. It is postulated that the result obtained in the lagoon was directly attributable to the development of the crust as mentioned earlier.

4.5 THICKENED SLUDGE BEDS

Thickened sludge from lagoon No. 1 was pumped to the "thickened sludge beds" for drying. Various depths of sludge were applied, with results as follows:

Depth (inches)	Drying Time
2-3	May 26 - June 7
	- completely dry
6-12	May 26 - June 30
	- dry with damp layer at bottom
12-18	Aug. 20 - April 5, 1966
	- not dry

The above results indicate that to achieve reliable drying of sludge in beds without under-drains, the sludge should be applied in layers not thicker than 12 inches.

Lagoon No. 1 - Test A

Date 1964	Sludge Addition Cum.Gals.	Cum. Lbs. Solids	% Solids	Decents Cum.Gals.	Cum. Lbs. Solids
Oct.9	20000	6200	3.1		
13	32900	10200	3.1		
15	54000	16530	3.0		
16	80500	32950	2.8		
17	102900	30670	3.0		
18	140100	41870	3.0		
19	179300	53630	3.0		
20	229300	68630	3.0		
21	279300	83630	3.0		
22	324600	96760	2.9		
23	384600	114160	2.9		
24	432400	128500	3.0		
25	464200	138040	3.0		
26	494500	146360	2.8	47700	1300
27	518800	153030	2.7		
28	548300	160700	2.6		
31	596000	172625	2.5		

Continued

Lagoon No. 1 - Test A

Date 1964	Sludge Addition Cum. Gals.	Cum. Lbs. Solids	% Solids	Decents Cum.Gals.	Cum. Lbs. Solids
Nov. 1	629300	181615	2.7		
2	644500	185715	2.7		
3	656500	188955	2.7		
16				124400	9100
Dec.13	729400	210825	3.0		
1965					
Jan. 1				344400	19700
9	789400	229425	3.1		
10	904400	265125	3.1		
13				427400	23600
17	1032400	307425	3.3		
Mar. 5				489700	26600
7	1094700	336725	3.9		
Apr.28				689700	29900
Total	1094700	336725		689700	29900
Average			2.95		
Remaining Sludge	405000	306825	7.6		

TABLE 1

LAGOON NO. 1 - TEST B

	Sludge Addition			Decents	
Date	Cum. Gals	Cum. Lbs. Solids	% Solids	Cum. Gals	Cum. Lbs. Solids
(adjusted for remaining sludge)					
1965	270500	83100		170500	7400
May 30	335100	102500	3.0		
June 1	692100	213900	3.3		
13					
19	748200	230900	3.0		
21	796400	246900	3.3		
22	824400	256700	3.5		
23	830000	258800	3.8		
24	844000	263200	3.1		
26	869000	271900	3.5		
27	890600	280600	4.0		
28	954100	313000	5.1		
29	978900	322900	4.0		
July 1	1014200	338100	4.3		
6				428000	19750
7	1033000	346900	4.7		
Aug. 9				553000	25750
Total	1033000	346900		553000	25750
Average			3.7		
Remaining Sludge	480000	321150	6.7		

TABLE II

LAGOON NO. 1 - TEST B

	Sludge Addition			Decents	
Date	Cum. Gals.	Cum. Lbs. Solids	% Solids	Cum.Gals.	Cum. Lbs. Solids
(adjusted for remaining sludge)					
1965	270500	83100		170500	7400
May 30	335100	102500	3.0		
June 1	692100	213900	3.3		
13					
19	748200	230900	3.0		
21	796400	246900	3.3		
22	824400	256700	3.5		
23	830000	258800	3.8		
24	844000	263200	3.1		
26	869000	271900	3.5		
27	890600	280600	4.0		
28	954100	313000	5.1		
29	978900	322900	4.0		
July 1	1014200	338100	4.3		
6				428000	19750
7	1033000	346900	4.7		
Aug. 9				553000	25750
Total	1033000	346900		553000	25750
Average			3.7		
Remaining Sludge	480000	321150	6.7		

TABLE II

LAGOON NO.1 - TEST C

	Sludge Addition			Decents	
Date	Cum.Gals	Cum. Lbs. Solids	% Solids	Cum. Gals	Cum. Lbs. Solids
(adjusted for remaining sludge)					
1965	479000	161000		256300	11900
Aug.20	502000	169800	3.8		
21	520700	177000	3.9		
23	544000	186300	4.0		
24	579100	202100	4.5		
25	600500	210700	4.0		
26	634300	223900	3.9		
27	675400	239500	3.8		
31	707600	252400	4.0		
Sept.1	751900	272300	4.5		
3	772500	281400	4.4		
4	814500	299900	4.4		
5	869500	324100	4.4		
6	886500	331600	4.4		
11	919500	346100	4.4	365400	16300
13	968400	367100	4.3		
14	980400	372200	4.3		
21				437400	19000

Continued.....

LAGOON NO.1
TEST C

Date	Sludge Addition Cum.Gals.	Cum.Lbs. Solids	% Solids	Decents Cum.Gals.	Cum. Lbs. Solids
Oct. 2				472800	20300
7	1025900	387700	3.4		
8	1077600	405300	3.4		
9	1102800	413900	3.4		
20	1112800	419500	5.6	620800	25800
21	1128800	425100	3.9		
Nov. 2	1158500	430200	1.5		
3	1173100	432400	1.5		
4	1198300	436200	1.5		
27	1242500	447700	2.5		
29	1277400	456400	2.5	705800	28800
30	1318600	466900	2.5		
Dec. 2				763600	46100
Total	1318600	466900		763600	46100
Average			3.6		
Remaining Sludge	555000	420800	7.6		

TABLE III

LAGOON NO. 2

Date	Sludge Addition Cum.Gals.	Cum.Lbs. Solids	% Solids	Decents Cum.Gals.	Cum. Lbs. Solids
1964					
Oct. 8	12000	2700	2.2		
14	24000	6725	3.4		
16	36900	10335	2.8		
20	48900	13925	3.0		
24	63700	18020	2.8		
27	75700	21155	2.6		
30	87700	24155	2.5		
Nov. 3	99700	27100	2.5		
6	114500	30255	2.1		
10	129800	33965	2.4		
13	145100	37465	2.3		
23				46500	1155
Dec. 8	191600	51415	3.0		
1965					
Apr.28				104200	1873
May 9	226600	78415	7.7		
11	245600	90015	6.1		
12	256000	97615	7.3		
13				111700	1998
16	263500	102615	6.7		

Continued

LAGOON NO.2

Date	Sludge Addition Cum.Gals.	Cum.Lbs. Solids	% Solids	Decents Cum.Gals.	Cum. Lbs. Solids
1965					
June 12				166200	2818
14	289100	113715	4.3		
15	318000	128665	5.2		
22				180100	3028
23	327200	132115	3.8		
24	332100	133855	3.7		
July 12				201700	3353
13	353700	141855	3.7		
20				214800	3550
21	366800	146705	3.7		
Aug. 5				229300	3782
6	382100	152445	3.7		
Total	382100	152445	3.8	229300	3782
Remaining Sludge	152800	148663	9.7		

TABLE IV

LAGOON NO. 3

Date	Sludge Addition Cum.Gals.	Cum.Lbs. Solids	% Solids	Decents Cum.Gals.	Cum. Lbs. Solids
1964					
Oct.14	12000	2822	2.4		
17	27000	7470	3.1		
27	39000	10805	2.8		
30	51900	14030	2.5		
Nov. 6	66900	17296	2.2		
13	82000	20974	2.4		
20	104500	26292	2.4	32600	785
Dec. 4					
11	137100	36072	3.0		
1965					
Apr.28				68900	1039
June 11				95300*	1039
1966					
Apr.5	182700**	36072			
Total	182700	36072	2.6	95300	1039
	87400	35033	4.0		

** net gain - precipitation and infiltration

* net loss - evaporation

TABLE V

SLUDGE VOLUME

REDUCTION

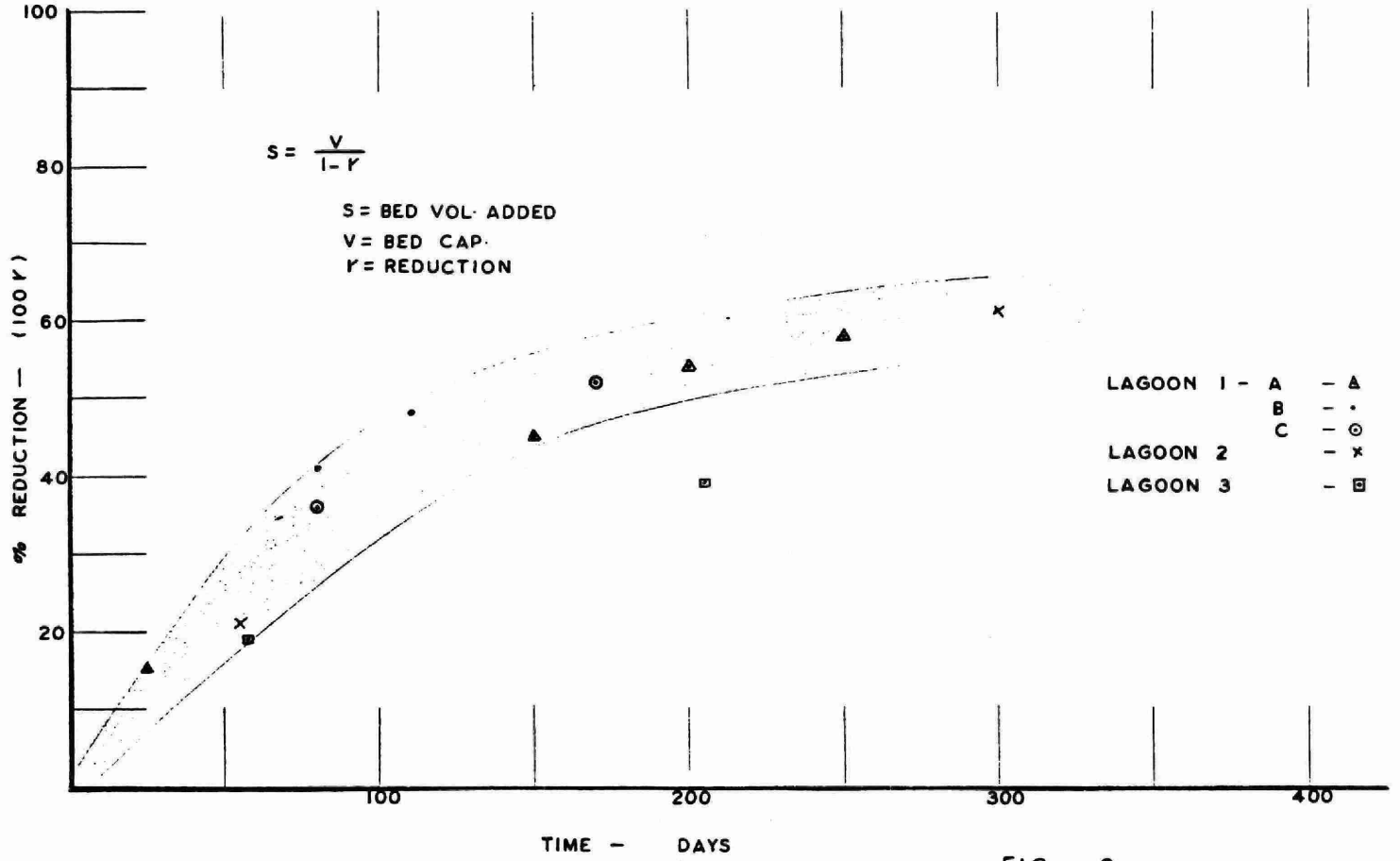


FIG. 8

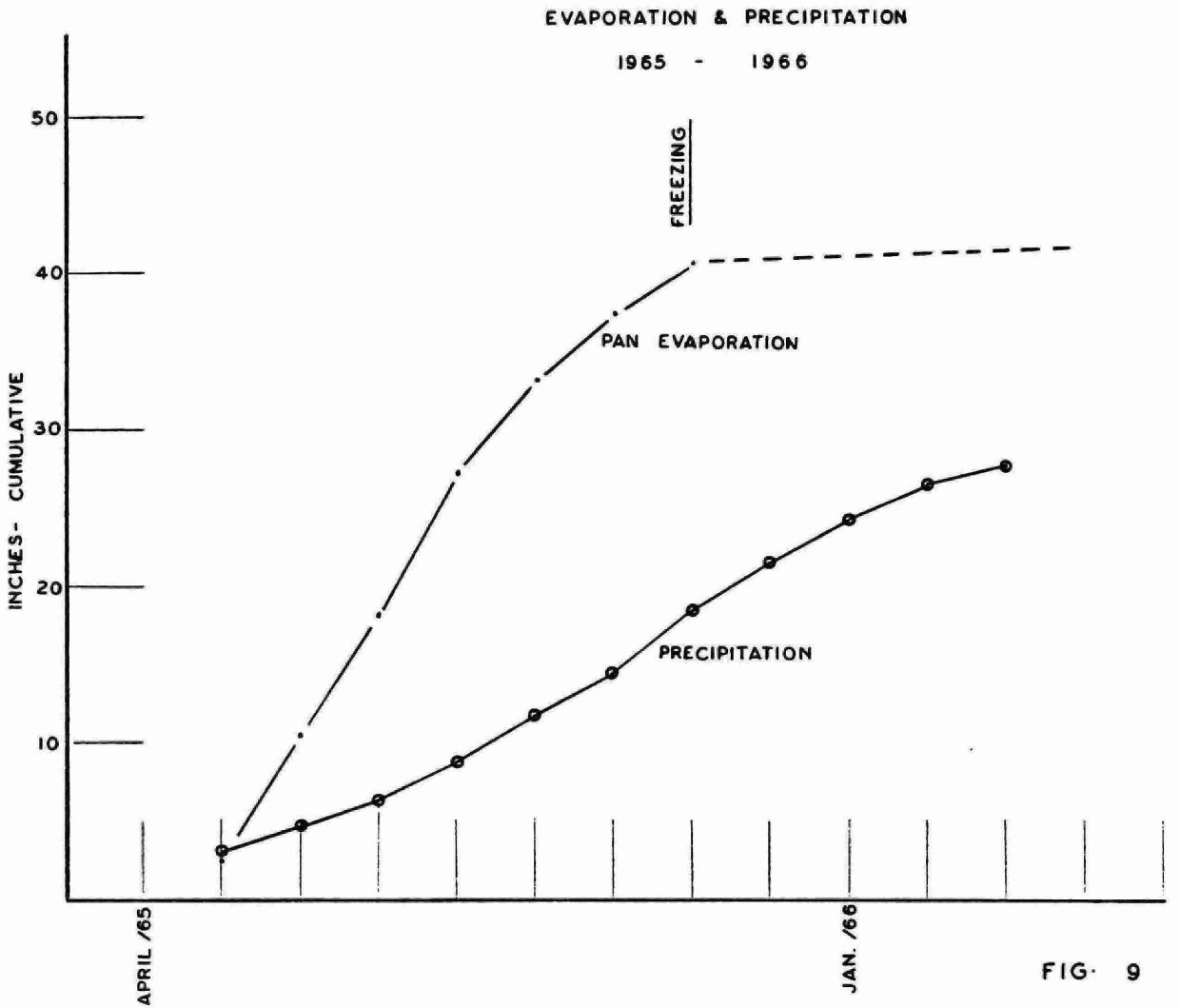

EVAPORATION & PRECIPITATION
1965 - 1966
FREEZING
PAN EVAPORATION
PRECIPITATION
INCHES- CUMULATIVE
50
40
30
20
10
APRIL /65
JAN. /66

FIG. 9

5.0 LABORATORY TESTING (MODEL STUDY)

5.1 GENERAL

In May, 1966, tests were conducted at the Lakeview STP using a glass front cabinet and digested sludge similar to that used in the pilot study lagoons. The glass cabinet made it easy to determine the amount and location of supernatant (if existant) and therefore the operation of the model approached the optimum usage which could be expected in a lagoon.

5.2 EQUIPMENT AND METHOD

A cabinet was constructed with three steel sides and a glass panel on the fourth side. Tank dimensions were 2'-0" x 2"-0" x 6'-0" high. The top was open and the bottom (steel) was fitted with a 2" dia. drain valve.

Supernatant draw-off was by means of a syphon. The draw-off point was selected according to the location of supernatant (indicated through the glass front). Volume of draw-off and subsequent re-filling with digested sludge was calculated from liquid level measurements.

Two tests were carried out, each one by essentially the same method. Sludge, to a depth of 60.75 inches, was placed in the cabinet. Inspections were made daily and supernatant drawn off (re-filled with sludge) when available. Results are shown in Figure 10.

5.3 RESULTS

Sludge volume reductions as obtained in the model study were approximately equal to those obtained in the full size lagoons but the time necessary to obtain such reductions was significantly less. It is pointed out however that the filling time of the model was negligible whereas the lagoons required from 30 to 50 days. It is concluded that a thickening lagoon should be capable of a sludge volume reduction of 50% in approximately 25 days in addition to the time required to add the necessary sludge volume to the pond.

SLUDGE CABINET TESTS

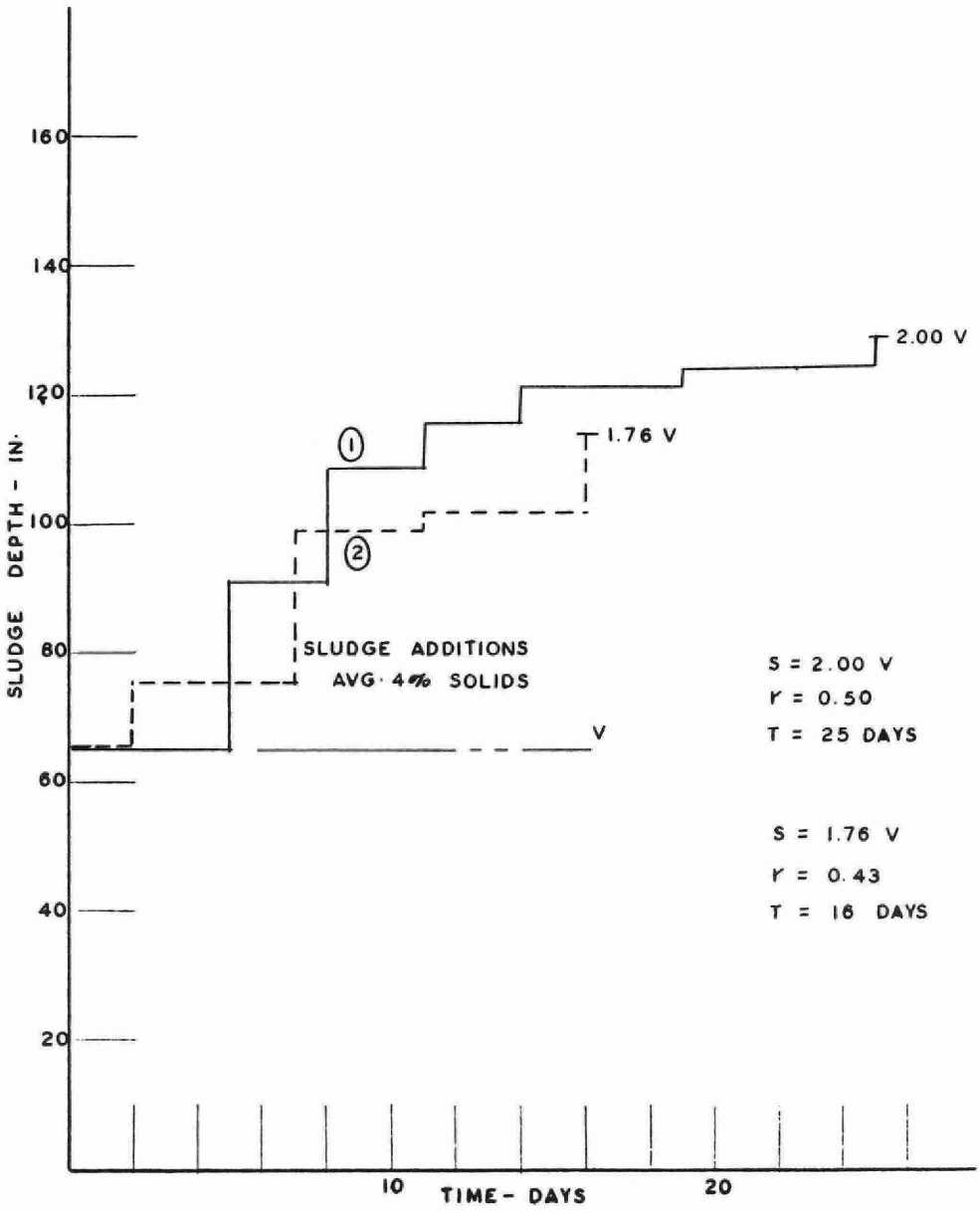


FIG. 10

6.0 CONCLUSIONS

Based on tests conducted by the Ontario Water Resources Commission Division of Research on the use of deep lagoons for the thickening and/or drying of digested sludge it is concluded that such lagoons are not effective when used with the intention of drying sludge. They are, however, effective in thickening sludge with volume reductions of approximately 40 to 50% being obtainable. Thickening is accomplished by filling with sludge, allowing a quiescent period, drawing off the available supernatant and refilling with sludge. The quiescent periods will vary but should be approximately 5 days. Alternate supernatant draw-off and sludge additions may be continued until the resulting supernatant volumes are negligible, but at this point the remaining sludge will be of such consistancy as to be impossible to pump with conventional equipment.

7.0 RECOMMENDATIONS

On the basis of tests as described in the foregoing sections, the following recommendations with respect to the use of sludge lagoons are presented:

1. Deep lagoons are not recommended for the purpose of drying sludge.

2. Deep lagoons are recommended for the thickening of digested sludge. The maximum volume reduction obtained will be approximately 50%.

3. The recommended thickening time is approximately equal to 25 days more than the time required to add the required volume of sludge to the lagoons.

4. The number of lagoons required should be calculated from the formula: -

$$\frac{V}{Q} \cdot n > 25+a$$

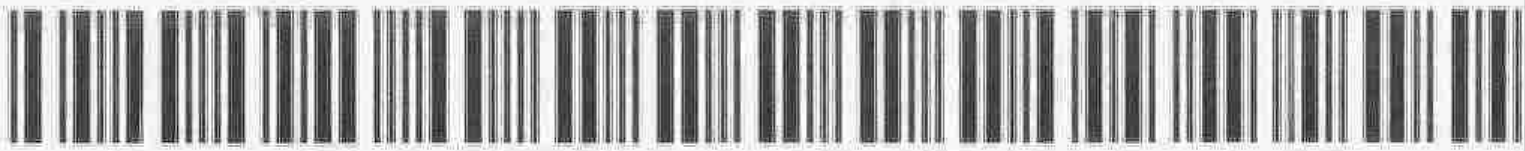
in which V = individual lagoon volume

Q = sludge, gallons per day

N = number of lagoons

a = time to empty lagoon, days.

5. Sludge thickening to a degree that standard removal procedures are impractical is not recommended. A consistancy of 11% solids is recommended as a maximum which may be easily pumped for ultimate disposal.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